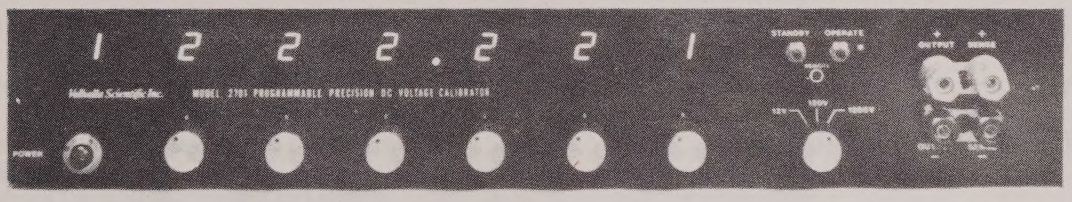
INSTRUCTION MANUAL MODEL 2701

CERTIFICATION

Valhalla Scientific, Inc. certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory. Valahalla Scientific, Inc. further certifies that its calibration measurementws are traceable to the National Bureau of Standards to the extent allowed by NBS's calibration facility.

WARRANTY

Valhalla Scientific, Inc. warrants this instrument against defects in material and workmanship for one year from date of shipment. We will repair or replace the instrument during the warranty period provided it is returned to Valhalla Scientific, Inc. No other warranty is expressed or implied. We are not liable for consequential damages. Permission must be obtained directly from the factory for warranty repair returns. No liability will be accepted if returned without such permission.



MODEL 2701
PROGRAMMABLE PRECISION DC VOLTAGE CALIBRATOR

SPECIFICATIONS

DC VOLTAGE RANGES	12 volts DC 120 volts DC 1200 volts DC
RESOLUTION	10 microvolts 100 microvolts 1 millivolt or 1 ppm.
ACCURACY (25°C ±3°C)	±0.0015% of setting, ±0.0015% of range.
TEMPERATURE COEFFICIENT	1 ppm/°C.
STABILITY	15 ppm/month; 50 ppm/6 months.
RIPPLE AND NOISE	0.005% of range RMS, all frequencies.
LINE REGULATION	2 ppm/volt of line change, 105 to 125 VAC or 210 to 250 VAC.
LOAD REGULATION	10 ppm from no load to full load.
CURRENT	20 milliamperes maximum, all ranges.
SETTLING TIME	Within 20 ppm of final value within 3 seconds, zero to full scale.
WARM UP TIME	Within 50 ppm of final value within 15 seconds.
ISOLATION	Optical: Output may float up to 500 volts from chassis potential.
SHORT CIRCUIT PROTECTION	Current limits at 25 milliamperes and automatically switches to STANDBY after 100 millisecond overload.
OPERATIONAL ENVIRONMENT	0 to 50°C, 0 to 80% relative humidity, to 10,000 ft.
STORAGE ENVIRONMENT	−20 to 85°C, 0 to 95% relative humidity, 30,000 feet.
FULL SCALE VOLTAGE	1222221 (Decimal point ignored).
POWER REQUIREMENTS	30 watts at 115 or 230 volts AC, ±10%, 50 to 60 Hz.
WEIGHT	15 pounds net; 18 pounds shipping weight.
SIZE	17 inches W, 3-1/2 inches H, 13 inches deep.

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SECTION I—GENERAL INFORMATION

1-1 DESCRIPTION

1-2 Valhalla Scientific's Model 2701 Programmable Precision DC Calibrator is a highly stable, precision DC voltage source. Front panel switches permit selection of output voltages from 10 microvolts through 1,222.221 volts in three ranges with a resolution of one part in one million.

1-3 The instrument uses a precision reference for output control. The voltage level of this reference is dependent on the duty cycle of a digital pulse generator which, in turn, is controlled by the setting of front panel voltage selection switches. Since this technique eliminates the shortcomings of conventional resistive voltage dividers, the accuracy and stability of the instrument are independent of switch contact resistance. Digital control of the pulse generator enables remote voltage selection through an optional IEEE-488 Interface.

1-4 The Model 2701 operates from 115 or 230 volt, 50-60 Hz AC commercial power and is equipped with a detachable power cord and connector.

1-5 OPTIONAL EQUIPMENT

1-6 A number of optional equipment items are available to increase the utility of the Model 2701 Programmable Precision DC Calibrator. These are described in the following paragraphs.

1-7 OPTION IEEE-488

1-8 Option IEEE-488 permits control of the Model 2701 through the IEEE-488 General Purpose Interface Bus. The bus coupler is mounted inside the instrument and a 24-pin IEEE-488 connector and address switch are mounted on the rear panel. This option may be factory installed at time the instrument is purchased or may be incorporated as a field retrofit. A separate instruction manual is furnished describing installation and operation.

1-9 OPTION C

1-10 Option C is a 48 inch shielded cable with a dual banana plug on one end, and alligator clips on the other.

1-11 OPTION BBC

1-12 Option BBC is a 48 inch shielded cable with dual banana plugs on both ends.

1-13 MODEL 2704

1-14 Valhalla Model 2704 is a precision resistive voltage divider with a fixed ratio of 100:1. When used with the Model 2704, the 2701 will provide 1.2 volts full scale with 1 microvolt resolution on the 120 volt range, and 0.12 volts full scale with 0.1 microvolt resolution on the 12 volt range. Its output impedance is 50 ohms.

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SECTION II—INSTALLATION

2-1 INTRODUCTION

2-2 This section of the manual contains information for receiving inspection and installation of the Model 2701 Programmable Precision DC Voltage Calibrator.

2-3 INITIAL INSPECTION

2-4 If the shipping container shows evidence of in-transit damage, such damage should be immediately brought to the attention of the carrier and the nature of the damage noted on the bill of lading.

2-5 Unpack the instrument and retain the shipping container until the instrument has been inspected for possible damage in shipment. If in-shipment damage is observed, notify the carrier and obtain his authorization for repairs before returning the instrument to the factory. If the shipping container shows evidence of damage in transit, but the instrument does not, it may be advisable to perform the calibration procedure of Section V to determine that the instrument has not sustained internal damage.

2-6 POWER REQUIREMENTS

2-7 The instrument requires 115 or 230 volts AC, 50-60 Hz, at 15 watts. A detachable line cord with an appropriate connector is provided.

2-8 INSTALLATION

2-9 Installation requires only that the line cord be plugged into a power receptacle. The instrument output appears on two banana jacks on the front panel. Two additional banana jacks serve as sensing inputs. These should be connected directly across the load terminals when the resistance of the leads between the instrument output and the load will produce a significant voltage drop. The sensing inputs cause the instrument to maintain the voltage across the load at that selected with the front panel switches. The sensing jacks are, otherwise, connected to their respective voltage jacks using the straps provided. If the optional IEEE-488 Interface is installed, the instrument may be connected to a computer or other controller through the IEEE-488 24-pin connector on the rear panel.

2-10 The Model 2701 is intended to be operated in environments where the temperature does not exceed 50°C (122°F). If higher ambient temperatures are anticipated, external means must be provided to maintain the temperature around the Model 2701 at or below 50°C.

SECTION III—OPERATION

3-1 INTRODUCTION

3-2 This section of the manual contains complete operating instructions for the Model 2701 Programmable Precision DC Voltage Calibrator.

3-3 FRONT PANEL CONTROLS AND INDICATORS

3-4 A push-on, push-off switch at the left of the front panel connects the external power source (115/230 VAC at 50/60 Hz) to the instrument's internal power supply circuits. Six twelve-position, rotary switches are located to the right of the power switch. Each controls a single decade (plus overrange and carry) of the output voltage selection. The switches are arranged in descending order, with the control for the least significant decade on the right. A zero-position reference mark is located on the panel above each switch.

3-5 A seven-segment LED display device is located directly above each switch to indicate the value selected in that decade. The seventh LED, located above the power switch, displays a "1" if the most significant decade switch is set at or above "10". The displays indicate the voltage selected by the switches when the instrument is in the operate mode. Since the output of the instrument is zero when it is in the standby mode, the displays show only zeros.

3-6 A three-position rotary RANGE selection switch is located to the right of the voltage selection switches. Full scale ranges of 12 volts, 120 volts, and 1200 volts are selectable and the selected range is indicated by illumination of one of three LED's.

3-7 Two pushbutton switches are located above the range switch to select the standby and operate modes. One of two LED's will be illuminated to indicate the mode of operation; a third LED (REMOTE) indicates when the instrument is being remotely controlled. The CURRENT LIMIT LED is illuminated when excess current is flowing in the output. When current limiting occurs, the CURRENT LIMIT LED will be illuminated.

3-8 REAR PANEL FEATURES

3-9 The line cord connector and the AC power fuseholder are located on the rear panel of the instrument. If the IEEE-488 Interface is installed, a 24-pin interface connector and an address switch are also located on the rear panel. Consult the IEEE-488 interface option manual for instructions on how to set the device address switch.

3-10 OPERATING PROCEDURE

3-11 Turn on power, wait five seconds, then press the OPERATE pushbutton. Select the desired range. Note that the decimal point will move from one digit display to another as the range switch is moved from one position to another. Set the six voltage selection switches so that the desired output voltage is indicated by the seven-segment displays. **Press the STANDBY button to remove the output voltage before making any connections at the output terminals.**

CAUTION

The voltage at the front panel output and sense terminals, when operating on the 120 and 1200 volt ranges, is dangerous to life. Contact with these terminals while the instrument is in the operate mode may result in serious injury or death. The user should exercise extreme caution to insure that the instrument is in the standby mode before connecting or disconnecting leads to the output or sense terminals.

3-12 Each rotary decade switch has positions from 0 to 11. To prevent display ambiguity when a switch is placed in position 10 or 11, a carry is automatically transferred to the next most significant decade, adding one to that decade.

3-13 In the event of an overload where the current is in excess of 20 milliamperes, but less than 25 milliamperes, the CURRENT LIMIT LED will be illuminated. If current is increased above 25 milliamperes, the instrument will automatically switch to the standby mode after 100 milliseconds. The STANDBY indicator will be illuminated and the output voltage, and the selected voltage display, will be reduced to zero. Operation may be resumed by reducing the current requirements of the load and then pressing the OPERATE button.

3-14 In some applications, the resistance of the leads between the instrument and the load may cause

the voltage across the load to be significantly less than that appearing at the instrument output terminals. To maintain the voltage across the load at the value selected with the Model 2701 front panel switches, external sense terminals have been provided so that true four-wire regulation may be used. To utilize this feature, disconnect the straps between the output and sense terminals. Connect separate leads between the output terminals and the load terminals. Connect the positive sense terminal to the positive terminal of the load. Connect the negative sense lead to the negative terminal of the load. Since current flow in the sense leads is negligible, the voltage at the sense inputs is that appearing across the load. The instrument then automatically adjusts its output voltage to compensate for the voltage drop in the output leads and to maintain the selected output voltage at the load terminals.

3-15 Instructions for remote operation through an IEEE-488 General Purpose Interface Bus are provided in the IEEE-488 Interface Option manual. Note that for safety reasons, the front panel STANDBY and OPERATE pushbuttons continue to operate in the remote mode.

SECTION IV—THEORY OF OPERATION

4-1 GENERAL

4-2 This section of the manual provides functional and detailed descriptions of the circuits of the Model 2701 Programmable Precision DC Calibrator. The functional descriptions are referenced to the block diagram of Figure 4-1, and are intended to assist the user in gaining a general understanding of the instrument prior to study of the detailed circuit descriptions. The material of this section, together with that of Section V, will provide the information necessary for maintenance of the instrument.

4-3 FUNCTIONAL DESCRIPTION

4-4 The Model 2701 comprises a coarsely regulated switching power supply feeding a series regulator. The output of the regulator is controlled by a precision variable reference voltage. A fixed voltage is precisely divided to produce the precision reference voltage. The division of the fixed voltage is accomplished, using digital techniques, by switching the reference on for a precise percentage of the time, determined by the setting of the front panel voltage selection switches. This produces a series of pulses with an average DC level precisely related to the pulse width. An oven-stabilized voltage reference provides the fixed voltage. The accuracy of the instrument is primarily detemined by the stability of this voltage and is in the order of 0.0015%. The following circuit descriptions are arranged under headings corresponding to the designators in Figure 4-1.

4-5 SWITCHING POWER SUPPLY

4-6 The primary power source for the series regulator is a 1500 volt, full-wave, filtered power supply. The circuit is conventional except that primary power to the power transformer is electronically switched. By interrupting the power input, the switching circuit provides coarse regulation of the power supply output at approximately 100 volts above the desired instrument output voltage. This feature minimizes the power dissipated in the series regulator. The circuit is designed to switch only at the time of zero crossing of the AC sine wave input.

4-7 SERIES REGULATOR

4-8 The series regulator consists of a group of transistors connected in series between the output of the switching power supply and the output terminals. An operational amplifier provides the control that determines the voltage drop across the transistors and, thus, the voltage appearing at the output terminals. When the sensing terminals are connected directly to the output terminals, the feedback to the operational amplifier causes it to compare the voltage at the output terminals with the reference voltage. The output of the operational amplifier forces the voltage at the output terminals to the level of the reference. If the sense inputs are connected across the load terminals, the comparison is between the voltage across the load terminals and the reference voltage. The selected output voltage is then maintained across

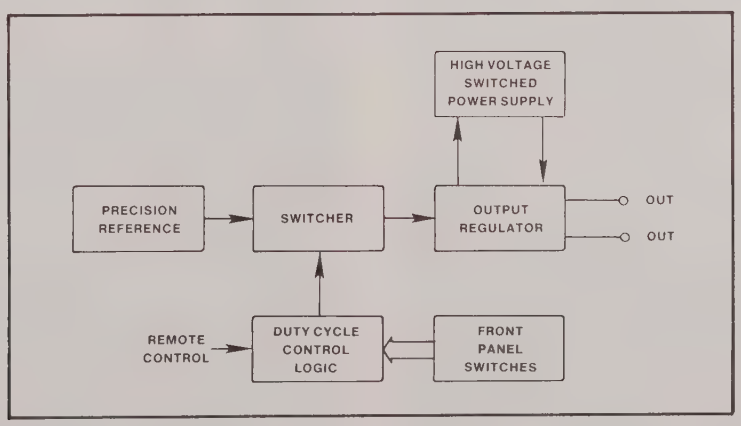


Figure 4-1. Block Digram, Model 2701 Precision DC Voltage Calibrator.

the load and the voltage at the instrument output terminals will rise to whatever level is necessary to compensate for the drop in the leads between the output terminals and the load terminals.

4-9 DIGITALLY CONTROLLED VARIABLE REFERENCE

4-10 The variable reference consists of an ultra-precise, variable duty cycle pulse generator driving an electronic switch of single pole, double throw configuration. The output of the switch alternates between a fixed, precise voltage level and ground. The pulse duty cycle is precisely determined by the duty cycle of the pulses driving the switch and the amplitude is determined by the precise voltage input level. Thus the average voltage level of the pulse train, after filtering, is precisely proportional to the pulse duty cycle. The duty cycle of the pulse generator is determined by BCD counter circuits, described in the following paragraph, which are controlled by the front panel switches or, alternately, by a remote controller through the optional IEEE-488 Interface.

4-11 CONTROL LOGIC

4-12 In response to signal inputs from front panel pushbuttons, the control logic selects standby or operate modes, and automatically selects standby when an overload occurs. A remote enable input from the optional IEEE-488 Interface will disable the front panel voltage selection switches and transfer control to an external controller.

4-13 DETAILED CIRCUIT DESCRIPTION

4-14 This section provides a detailed description of each circuit of the 2701 DC Calibrator. Unless otherwise specified, the reference designators appearing in this section are those of the schematic diagrams, Figures 5-3 and 5-4. Where multiple circuit IC's are involved, the individual circuits are identified by their output terminal numbers. For example, IC44-10 identifies that circuit of quad NOR gate IC44 that has its output connected to pin 10.

4-15 To facilitate an understanding of circiuit operation, a simplified diagram of the high-voltage power supply and output regulator circuits is included as Figure 4-2. Its purpose is to provide an overall view of the circuit interconnections. It is not intended to replace the complete schematics, although the reader may wish to refer to this diagram as well as those of Figures 5-3 and 5-4. Note that all circuit components are not included in Figure 4-2 and, also, that some that are may not be identified.

4-16 SWITCHING POWER SUPPLY

4-17 The switching power supply provides the power for the instrument's series regulator which provides the output voltage. Primary power is applied to transformer T1 through a diode bridge consisting of diodes CR42 through CR45. Transistor Q20, connected across the DC output terminals of the diode bridge, is driven by Q19. Q19 is driven, through optical isolator IC6, from comparator IC3 and zero crossing detector IC5. The bridge acts as an open circuit unless Q20 is conducting. When Q20 is turned on, the bridge conducts in both directions, permitting the primary AC to pass to the transformer. With Q20 conducting continuously, the bridge consisting of CR50 through CR53, connected to the secondary of T2, rectifies the AC, providing approximately 1500 volts DC to filter capacitors C9 through C12. Lower voltages are produced when Q20 does not conduct continuously. Resistors R128-R145 equalize the voltage across the filter capacitors. Note, as shown in Figure 4-2, that the high voltage power supply has a resistance path from positive to negative which is tapped to provide a ground connection. The drop across the resistance from positive to ground will be maintained at approximately 100 volts by the circuit of IC3 and IC5. IC2 utilizes the drop across the resistance connected from ground to the negative terminal as a sense input to the summing junction at its non-inverting input.

4-18 Power supply switching is controlled by a gated comparator circuit comprised of operational amplifier IC3 and associated components. The output of the comparator can change state only during the zero crossings of the AC input sine wave.

4-19 CR11 and CR12 are connected to opposite ends of a secondary winding of T1. Thus, during a narrow "window" that extends to either side of the zero crossing point of the AC input, the inverting input of IC5 will be high, forcing its output high. This will forward bias CR8 and apply a fixed bias of approximately +2.5 volts at the inverting input of IC3 to which the voltage at the junction of R36 and R37 is compared. If the junction voltage is lower than that at the non-inverting input, the output of IC3 will be forced high, turning off the LED in optical isolator IC4 which will place (or maintain) Q20 in conduction. If the junction voltage is higher than that at the non-inverting input, the output of IC3 will go low, turning on the LED in IC4 which will turn off Q20. When the AC input to CR11 or CR12 moves outside the "window", the output of IC5 goes low, back biasing CR8 and removing the bias from the non-inverting input of IC3.

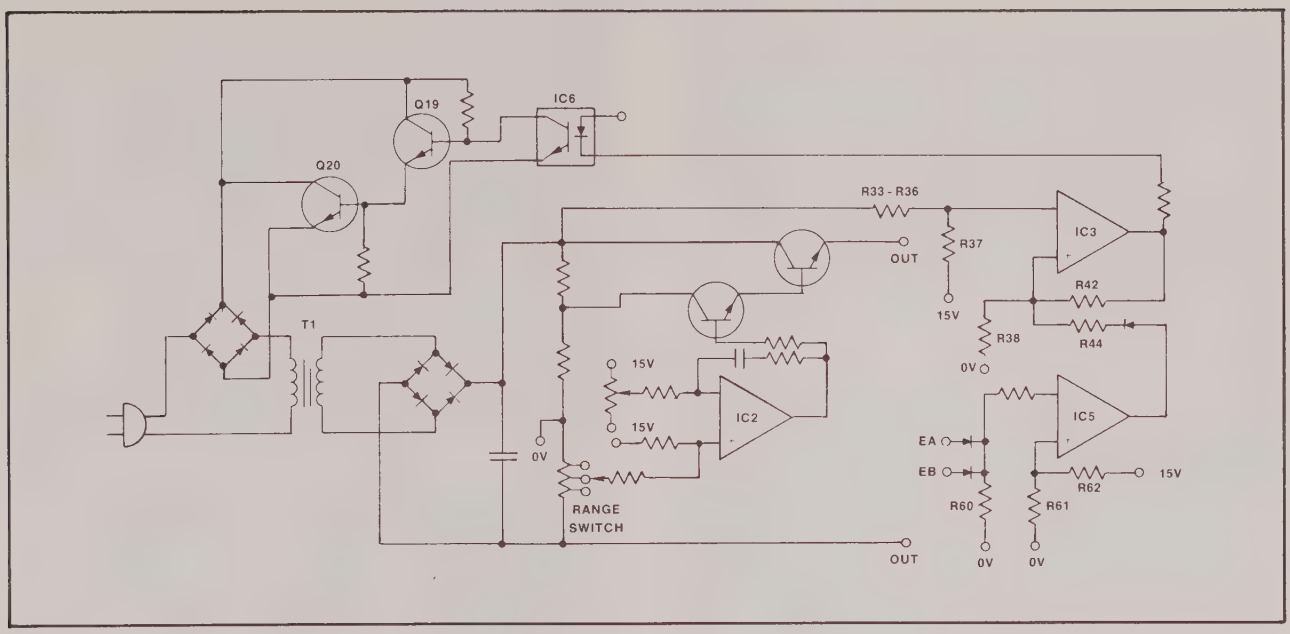


Figure 4-2. Simplified Schematic Diagram, Model 2701 Precision DC Voltage Calibrator.

This allows the positive feedback, through R42, to hold the output of IC3 at the high or low limit to which it was driven as a result of the input comparison. Thus, between zero-crossings of the AC input, the output of IC3 remains at one limit or the other.

4-20 The resistor values of the voltage divider are chosen so that whenever the voltage drop across the total resistance exceeds 100 volts, the output of IC3 will go low, turning on the LED in IC6. When the voltage drop falls below 100 volts, the output of IC3 goes high turning off the LED in IC6 which causes Q20 to conduct. The switching power supply output is thus maintained such that the drop across the series regulator transistor bank is maintained at approximately 100 volts.

4-21 When the operator selects a higher output voltage, the switching power supply can respond rapidly by allowing Q20 to conduct continuously until the selected voltage is reached. Zener diode CR7 prevents the voltage applied to the inverting input of IC3 from exceeding 6.2 volts. A selected decrease in voltage can only be accomplished by discharging the filter capacitors. To provide a quick discharge path, a winding on T2 is rectified by CR54 and filtered by C14, producing approximately 500 volts DC. The output of this supply is connected to the negative output of the switching power supply through R132. The result is that even at moderate output voltages, the filter capacitors can be discharged quickly with this reverse current. The current flow is from ground through CR55, the transformer secondary, C14 and R132.

4-22 SERIES REGULATOR

4-23 The series regulator reduces the output of the switching power supply to the precise voltage selected with the front panel switches. It also limits the output current to 25 milliamperes if a short circuit is applied to the output terminals. If the overload exists for approximately 100 milliseconds, it provides an output to the control logic to place the instrument in the standby mode. The series regulator consists of transistors Q7 thrugh Q18, operational amplifiers IC2 and IC4, and optical isolator IC7. IC2 is a precision instrumentation amplifier.

4-24 The odd numbered transistors drive the bases of the even numbered transistors which pass the instrument's output current. Voltage regulation is provided by Q17 and Q18. Under steady-state conditions, the drop across Q7 through Q18 is held to approximately 100 volts by the switching power supply as described in 4-17. Therefore, the voltage at the collector of Q18 is at approximately 17 volts. For a brief period after a sudden decrease in output voltage selection, the drop across the series regulator will be much greater than 100 volts, as discussed in paragraph 4-20. During such periods, the entire string of transistors will safely share the large voltage drop and the power dissipation.

4-25 IC2 serves as a comparator controlling Q17 and Q18. The output of the variable reference is compared with a voltage that is proportional to the instrument's output voltage. Contacts of relays K1 and K2 select the appropriate combination of R39, R40, R41, R45 and R46 for each of the instrument's voltage ranges so that the voltage at the junction of R39 and R40 is within the input range of IC2. The contacts of K1 are closed for the 12 volt range, the contacts of K2 are closed for the 1200 volt range and the contacts of both relays are open for the 120 volt range.

4-26 The current from the series regulator flows through R14. When the current reaches approximately 25 milliamperes, the voltage drop across R14 is sufficient to forward bias CR2 and DS8, pulling Q17 and Q18 toward cutoff. This portion of the circuit limits the output current if a short circuit occurs. DS8 is the front panel OVERLOAD indicator and is illuminated when the current exceeds 20 milliamperes. IC4 monitors the voltage at the non-inverting input of IC2. The voltage at that point is nominally zero because the negative input of the divider balances the positive reference voltage. If a short circuit occurs, the output voltage drops and the voltage at the non-inverting input of IC3 swings positive. R51 and C5 delay IC4's reaction to this change for approximately 100 milliseconds. The output of IC4-6 then goes high, turning on the LED in optical isolator IC7. The photo-transistor in IC7 then conducts, grounding the input to NOR gate IC44-11. The instrument is then placed in the standby mode in the same manner as if the STANDBY push button had been pressed.

4-27 DIGITALLY CONTROLLED VARIABLE REFERENCE

4-28 The variable reference provides a very precise voltage which is proportional to the settings of the front panel voltage select switches, or to BCD inputs through the optional IEEE-488 interface. It consists of IC1, IC8 through IC42, IC47, DS1 through DS7, and Q1 through Q4. IC47 is a highly accurate, oven-stabilized +7 volt reference. Field effect transistors Q2 and Q4 form a single pole double throw switch. Their output feeds reference filter IC1 via R18 and R20. When Q2 conducts, the switch output is connected to the 7 volt reference. When Q4 conducts, the switch output is connected to ground. A variable reference is produced at the output of the switch by alternately switching on Q2 and Q4, using a pulse of precisely adjustable duty cycle. To illustrate, a 50% duty cycle pulse would result in a reference voltage of 3.5 volts; a 25% duty cycle pulse would produce 1.75 volts, and so on.

4-29 There are two variable duty cycle pulse generators in the variable reference circuit. One is controlled by the three highest order switch decades, the other by the low order switch decades. The operation of the latter is typical of both, and will be described in detail. The block diagram of Figure 4-3 shows how the integrated circuits in this section are interconnected.

4-30 A crystal-controlled, one megahertz clock, IC42, drives a pair of three-decade counters which both run continuously. The reference counter, IC18 through IC20, consists of three TTL up-down counters connected in the down-count mode. Each time the count reaches 000, the reference counter outputs a pulse. The pulse is the clock input to one half of dual D flip flop IC13. The data input of IC13 is grounded, so that the pulse resets the flip flop. The same pulse is also the LOAD input of the presettable counter which consists of counters IC32 through IC34 connected in the count-down mode. Each time the presettable counter reaches count 000, it outputs a pulse to the SET input of flip flop IC13.

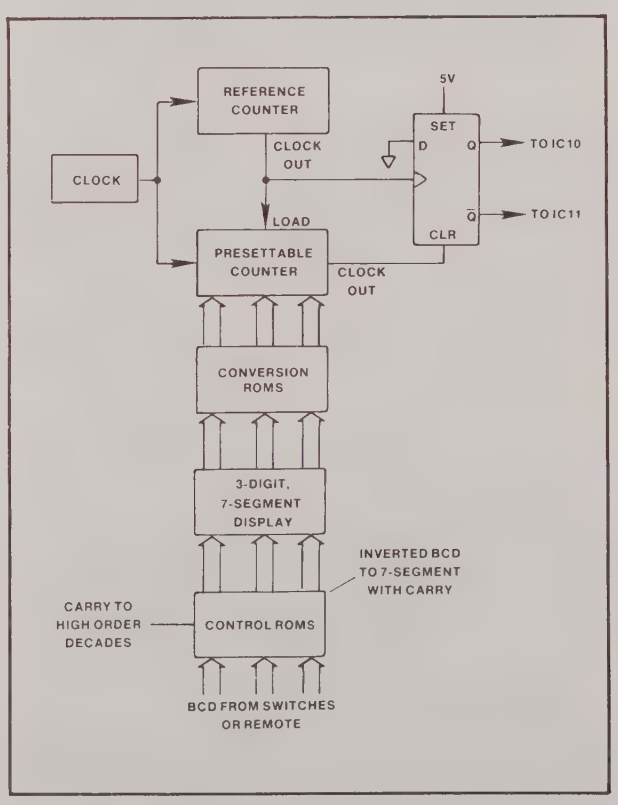


Figure 4-3. Block Diagram, Variable Reference Source.

4-31 The parallel data inputs of IC32-IC34 are fed indirectly from the voltage selection switches, or the optional IEEE-488 interface, in the following manner. BCD voltage selection codes from the switches, or from the IEEE-488 interface, are fed to the address inputs of IC39 through IC41, which are 256-bit, programmable read-only memories (PROM's). These are the control PROM's and are organized as thirty-two 8-bit words. They are programmed to convert BCD at their address inputs to seven-segment display codes at their data outputs, to furnish a carry to the next higher order decade for inputs of ten or eleven and to provide an output one number higher than the BCD input when a carry is received from a lower order decade.

4-32 The data outputs of the control PROM's drive seven-segment displays DS5 through DS7, and feed the inputs of conversion ROM's IC32 through IC34. The conversion ROM's are CMOS seven-segment to BCD converters. The outputs of the conversion ROM's are always BCD numbers between 000 and 999, because all carries have been performed by the control PROM's. These outputs are fed to the parallel data inputs of the presettable counter.

4-33 A typical counting sequence occurs as follows. An input number, less than 999, is placed on the data inputs of the presettable counter. When the reference counter next reaches the count of 000, the input number is loaded into the presettable counter. The reference counter is next at 999, and the presettable counter is at the input number. The two counters count down simultaneously. The presettable counter, since it was loaded with a number less than 999, reaches its terminal count first, setting flip flop IC13. Later, the reference counter reaches 000, resetting IC13. The process is then repeated, and continues at a rate of 1000 times per second. The output of the flip flop is a pulse with a 1000 Hz repetition rate. The duty cycle of the pulse is proportional to the BCD digits at the control PROM inputs. Selecting 999 yields a pulse with a duty cycle of 99.9%; selecting 500 produces a 50% duty cycle, etc.

4-34 The Q and Q outputs of flip flop IC13 control the conduction periods of FET switch transistors Q2 and Q4, to which they are coupled through optical isolators IC10 and IC11, respectively. Q2 is connected to the 7 volt reference, and Q4 is connected to ground. At the point where the two FET's are connected together, a series of positive-going pulses are produced with their peaks at precisely +7 volts and their negative peaks at 0 volts. The duty cycle is identical to the output of IC13. The pulse passes through R16, R18, R20, R21, R23 and R24 to the junction of C3 and C7. The circuit of IC1 is a capacitance multiplier that filters the pulse input, producing an output that is the average value of the pulsed input. This average voltage is dependent on the input duty cycle, which is determined by the front panel switch settings and may be any of 1000 precisely repeatable values.

4-35 The high order section of the variable reference consists of reference counters IC14 through IC17, presettable counters IC21 through IC24, conversion ROM's IC28 through IC31, displays DS1 through DS4, and control PROM's IC35 through IC38. The high order counters differ from the previous description in the following respects. First, there is a fourth decade. Its purpose is to accept a carry from the next decade; therefore, there is no switch connected to it. Display DS1 is driven by its control PROM, IC35, and displays a "0" or a "1".

4-36 Second, the reference counter is loaded to the count of 1299 each time it reaches 0000. This requires the use of both halves of dual flip flop IC12. One half functions as does IC13, loading the presettable counter, while the other is used to provide the reference counter's clock pulse. The data input of IC12 is tied to ground. When the reference counter reaches 0000, it drives the clock input of IC12, resetting it. The output at IC12-5 then loads the counter. IC12 is set one count later by the signal from the 1-MHz system clock. As a result, the reference counter counts down from 1299 to 0000, then, a few nanoseconds later, it is again preset to 1299 to begin a new cycle. There are a total of 1300 counts in the sequence.

4-37 The switch transistors for the high order portion of the variable reference are Q1 and Q3. The outputs of the high order and low order switches are combined at the junction of R16, R17 and R18. Note that the ratio of the series combination of R18 and R20 to R17 is 1300:1 with R18 set at midrange. This ratio establishes the relative weights of the pulses from the high order and low order decades. The two pulses are combined in a 1300:1 ratio, filtered as described in paragraph 4-34 and provided some additional filtering by R25 and C4. The filtered voltage is applied to the non-inverting input of IC2. The output of IC2 is then applied to the base of Q17 as the reference voltage for series regulator, as described in paragraph 4-26.

4-38 CONTROL LOGIC

4-39 The control logic selects standby, operate and remote modes in response to control inputs. Operate and standby may be selected using front panel push buttons. Standby may also be selected automatically, as described in paragraph 4-26. The remote mode may be selected only by an external device through the optional IEEE-488 interface. The control logic consists of one half of a CMOS dual D flip flop, IC43, and a CMOS quad NOR gate, IC44, and transistors Q5, 6, 21, 22 and 23.

4-40 When the OPERATE push button is pressed, it places a logic low on IC44-1 and IC44-2. A high is produced at IC44-3, which operates the set input of the flip flop IC43, setting its pin 12 low. Pin 12 is connected to IC44-8. Since the output of IC44-9 is always low unless the system is in the remote control mode, a high is produced at IC44-10. This turns on Q6, placing a ground on the wipers of all the voltage select switches. With ground applied to their wipers, the switches produce inverted (ground true) BCD codes. The control ROMs, IC35 through IC41, are programmed to accept the inverted codes.

4-41 When the STANDBY push button is pressed, it resets flip flop IC43 which sets its pin 12 low. The switch wipers are pulled up by R121 causing all of the inputs to the control ROM's to be high. Since all of the inputs to the ROM's are zeros, the output of the instrument drops to zero. Pin 12 of IC43 is also connected to the base of Q21. Q21, when turned on, completes the circuit for the STANDBY LED, DS13, and turns Q22 off. When Q21 is turned off, Q22 is turned on and completes the circuit for the OPERATE LED.

4-42 Remote control is initiated by placing a low, from the IEEE-488 interface, on IC44-6. This low turns on Q23 to complete the circuit for the REMOTE LED, DS12.

4-43 INSTRUMENT POWER SUPPLY

4-44 The instrument power supply, as distinguished from the switching power supply, provides power for the instrument's internal circuits.

4-45 The operational amplifiers in the instrument are powered by positive and negative 15-volt supplies. The power source is transformer T2. Its output is rectified by diodes CR56 to CR59 and filtered by C15 and C18. IC45 and IC46 regulate the two rectified outputs to +15 volts and −15 volts respectively.

4-46 A positive 12 volt unregulated supply, consisting of CR46, CR47 and C19, provides power to the range-select relay coils. Power for the logic ICs and displays comes from an unregulated +5 volt supply consisting of CR48, CR49 and C20.

SECTION V—MAINTENANCE

5-1 INTRODUCTION

5-2 This section provides maintenance information for the Model 2701 Programmable Precision DC Calibrator. Included are a recommended test equipment list and calibration procedures.

5-3 RECOMMENDED TEST EQUIPMENT

5-4 This procedure requires the following items of test equipment:

Precision Kelvin-Varley Voltage Divider	John Fluke Model 720A, or equivalent.
Voltage Reference Standard	John Fluke Model 731B, or equivalent.
Null Detector	John Fluke Model 845AB, or equivalent.
Digital Voltmeter	10 microvolt sensitivity with accuracy of 0.01% or better.

5-5 CALIBRATION PROCEDURE

5-6 The following procedure should be performed at routine intervals to insure that the instrument remains within specified limits. In addition, calibration should be performed whenever repairs have been completed involving accuracy determining components.

CAUTION

The voltage at the front panel output and sense terminals may be dangerous to life. Contact with the terminals while the instrument is in the operate mode may result in serious injury or death. The user should exercise extreme caution to insure that the instrument is in the standby mode before connecting or disconnecting leads to the output or sense terminals

5-7 Connect the test equipment to the instrument as shown in Figure 5-1. Verify that the sense terminals on the Model 2701 are strapped to their respective output terminals.

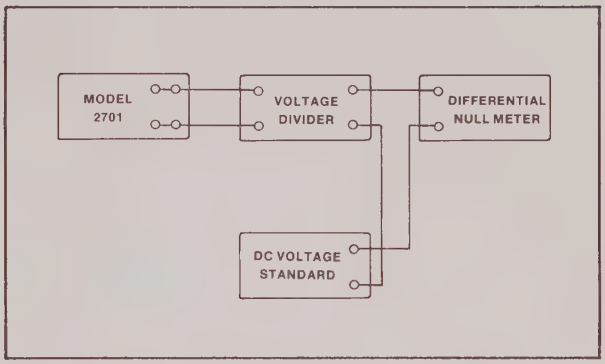


Figure 5-1. Test Equipment Connections.

5-8 Apply power to the Model 2701 and allow one hour for warm-up. Set the 2701 in the standby mode and on the 12 volt range. Set the reference standard to zero output. Set the voltage divider to 0.999999. Adjust R26 so that the null detector indicates a null within ±150 microvolts.

5-9 Set the reference standard for 10 volts output. Place the Model 2701 in the operate mode and the 12 volt range, and set the switches to 10.00000. Set the divider to 1.000000. Adjust R23 so that the null detector indicates a null within ±300 microvolts.

5-10 Set the voltage divider to 0.100000. Set the 2701 to 100.0000 volts output. Adjust R41 for an indication of less than ±300 millivolts on the nullmeter.

5-11 Set the voltage divider to 0.010000. Set the 2701 to 1000.000 volts output. Adjust R46 for an indication of less than ±300 microvolts on the nullmeter.

5-12 Place the 2701 in the 12 volt range and set the switches to 00.00999. Connect the DVM across the output terminals of the 2701. Set the 2701 to standby and adjust R26 for a reading on the DVM that is as close as possible to zero. Set the 2701 MODE SWITCH to OPERATE and adjust R18 for a DVM reading of 9.990 millivolts.

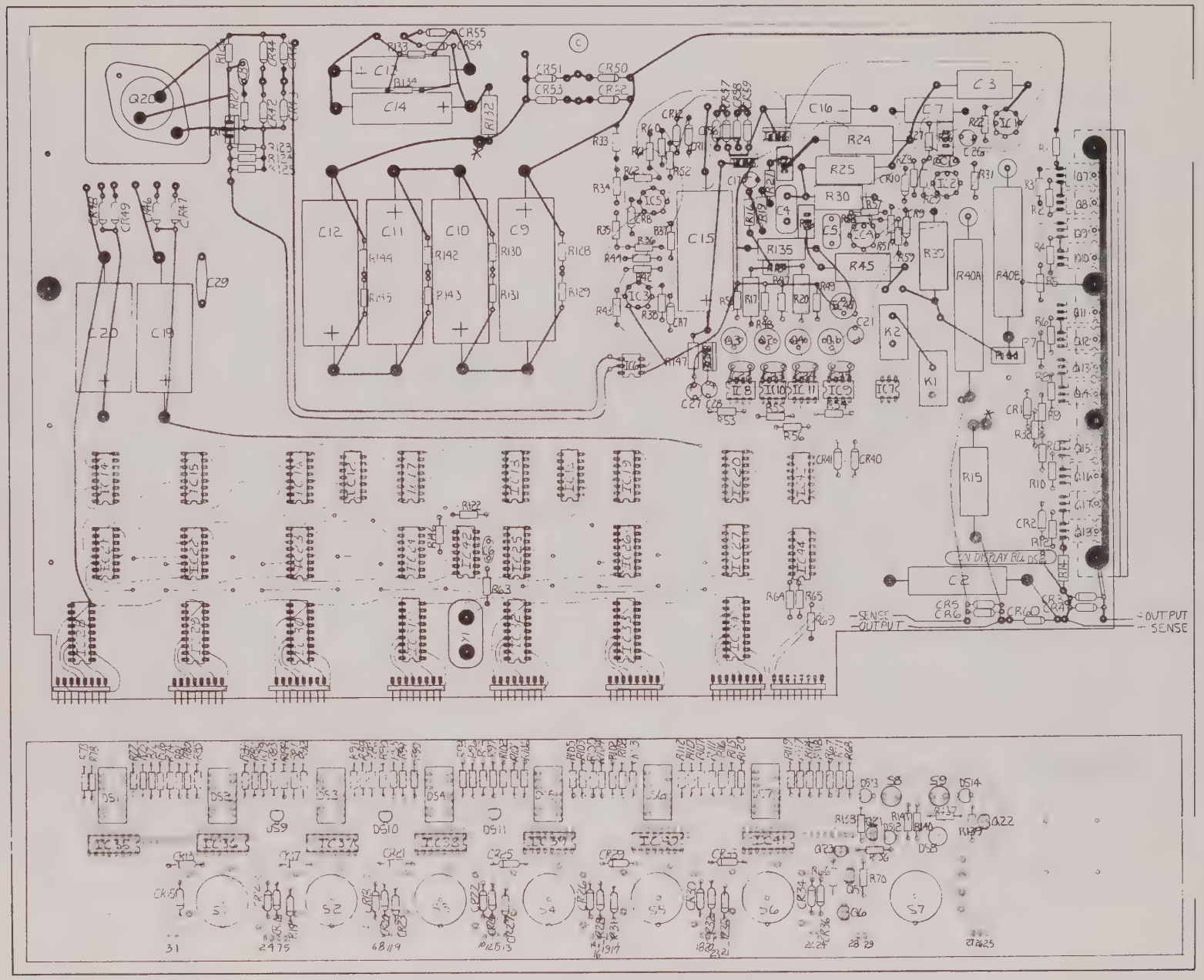
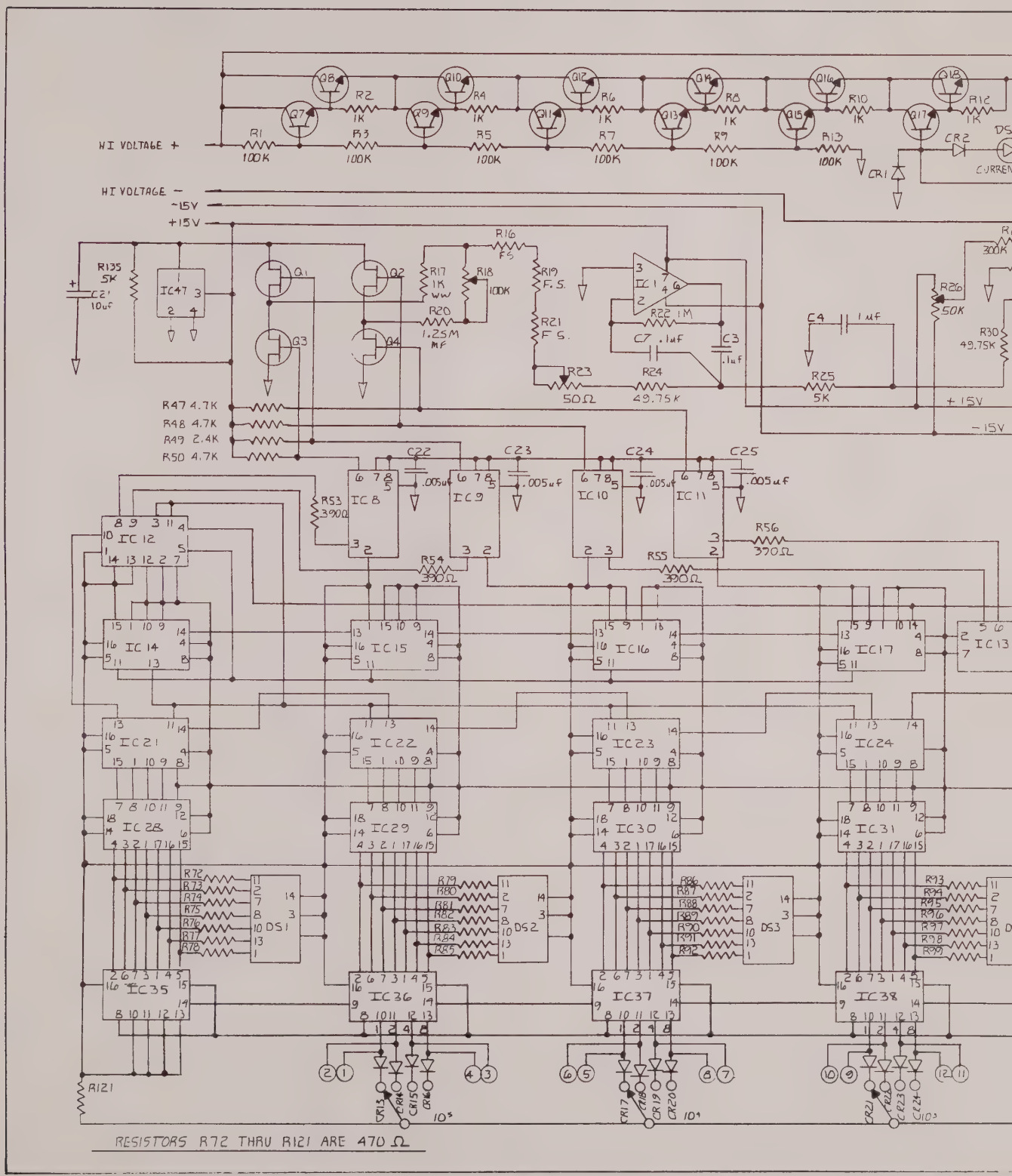


Figure 5-2. Assembly Diagram, Main Circuit Board and Display Board.


HI VOLTAGE +
HI VOLTAGE −
−15V
+15V
Q1
Q2
Q3
Q4
Q7
Q8
Q9
Q10
Q11
Q12
Q13
Q14
Q15
Q16
Q17
Q18
R1 100K
R2 1K
R3 100K
R4 1K
R5 100K
R6 1K
R7 100K
R8 1K
R9 100K
R10 1K
R12 1K
R13 100K
CR1
CR2
R16 FS
R17 1K ww
R18 100K
R19 F.S.
R20 1.25M MF
R21 F.S.
R22 1M
R23 50Ω
R24 49.75K
R25 5K
R26 50K
R30 49.75K
C2 10uf
C3 .1uf
C4 1uf
C7 .1uf
IC1
IC47
R47 4.7K
R48 4.7K
R49 2.4K
R50 4.7K
R53 390Ω
R54 330Ω
R55 330Ω
R56 330Ω
C22 .005uf
C23 .005uf
C24 .005uf
C25 .005uf
IC8
IC9
IC10
IC11
IC12
IC13
IC14
IC15
IC16
IC17
IC21
IC22
IC23
IC24
IC28
IC29
IC30
IC31
IC35
IC36
IC37
IC38
DS1
DS2
DS3
R72
R73
R74
R75
R76
R77
R78
R79
R80
R81
R82
R83
R84
R85
R86
R87
R88
R89
R90
R91
R92
R93
R94
R95
R96
R97
R98
R99
R121
CR13
CR14
CR15
CR16
CR17
CR18
CR19
CR20
CR21
CR22
CR23
CR24
RESISTORS R72 THRU R121 ARE 470 Ω

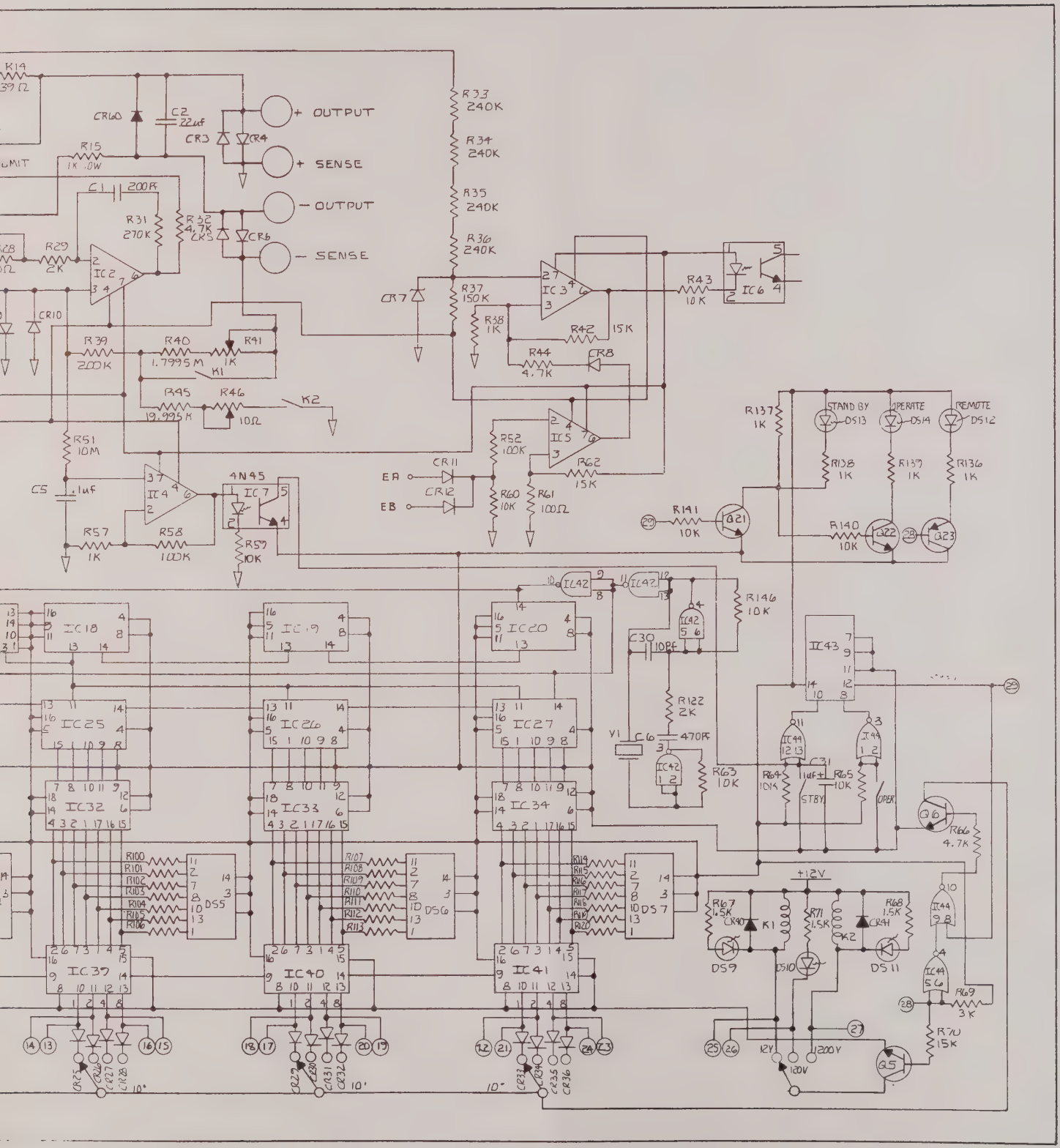


Figure 5-3. Schematic Diagram, Model 2701. Sheet 1.

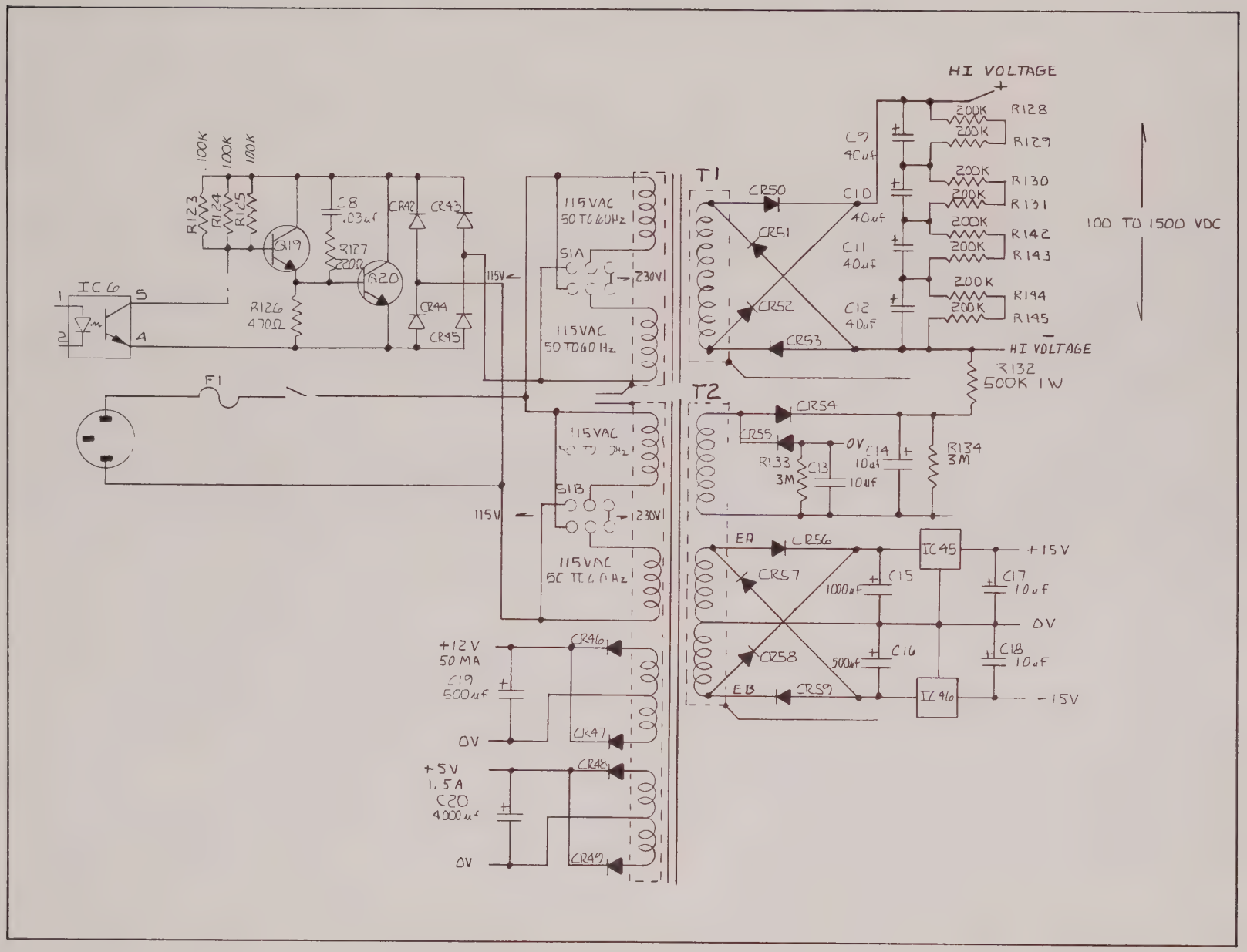


Figure 5-4. Schematic Diagram, Model 2701, Sheet 2.

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PARTS LIST

REF. DES.	V.S. P/N	DESCRIPTION	MFG.	MFG. P/N
C 1	2-10001	CAP, CERM 200Pf	56289	5GAT20
C 2, 36	2-80003	CAP, MYLAR .22µf	Electron	EP37478
C 5, 29	2-60002	CAP, PAPER .1µf	56289	225P10491
C 4	2-80002	CAP, MYLAR 1µf	12406	Z5A105
C 6	2-20009	CAP, MICA 470Pf	81349	CM05FD471J03
C 8	2-10004	CAP, CERM .02µf/500V	56289	5GAS20
C 9, 10, 11, 12	2-40009	CAP, ELEC 40µf/450V	56289	TVA-1712
C 13, 14	2-40011	CAP, ELEC 10µf/350V	56289	TVA-1604
C 15	2-40010	CAP, ELEC 1000µf/25V	56289	TVA-1211
C 16, 19	2-40008	CAP, ELEC 470µf /25V	56289	TVA-1209
C 17, 18, 21, 26, 27, 28	2-30001	CAP, TAN 10µf/16V	05397	T360B106M025AS
C 20 35	2-40000	CAP, ELEC 4000µf/15V	56289	39D308G015J14
C22-25	2-10000	CAP, CERM .005µf	56289	5GAD50
C 3, 7	2-50001	CAP, POLY .1µf/50V	ELPAC	PD5B104
C 33	2-20012	CAP, MICA 10Pf	81349	CM05FD100J03
C 31	2-30004	CAP, TAN 1µf	05397	T360B105M010AS
C32		FACTORY SELECT		
CR 1-6, 46-49, 56-59	3-20002	DIODE, RECT	04713	1N4001
CR 7	3-20005	DIODE ZENER 6V	04713	1N5234
CR 8, 11, 12-36, 40, 41	3-20000	DIODE	04713	1N914
CR 9, 10	3-20006	DIODE	07263	FD300
CR 42-45, 54, 55	3-20015	DIODE RECT	04713	1N4007
CR 50-53, 60	3-20016	DIODE HV	04713	MR250-2
DS 1-7	5-01010	DISPLAY 0-9	28480	5082-7650
DS 8	5-01011	LED - RED	28480	5082-7655
DS 9-14	5-01006	LED - RED SMALL	00001	MV5074
IC 1, 2	3-30041	IC OP-AMP	Burr Brown	3521L
IC 3, 4, 5	3-30074	IC OP -AMP	27014	LF356H
IC 6, 7	3-30094	IC OPTO-ISO	28480	4N45
IC 8, 9, 10, 11	3-30093	IC OPTO-ISO	28480	HCPL-2601
IC 12, 13	3-30095	IC DUAL D FLIP-FLOP	01295	74LS74
IC 14-27	3-30047	IC UP-DOWN COUNTER	02335	74LS190
IC 28-34	3-30080	IC 7 SEGMENT TO BCD	27014	74C915
IC 35-41	3-30082	IC PROM	01295	74S288N
IC 42	3-30027	IC QUAD NAND	86684	CD4011BE
IC 44	3-30024	IC QUAD NOR	86684	CD4001BE
IC 43	3-20026	IC DUAL D FLIP-FLOP	86684	CD4013BE
IC 45	3-30036	IC REG POS	27014	LM340T-15
IC 46	3-30037	IC REG NET	27014	LM320T-15
IC 47	3-30096	IC REFERENCE	27014	LM199AH20
IC 48	3-30034	IC REG POS	27014	LM340T-5

MODEL:	TITLE:	SHT OF
2701	DC VOLTAGE CALIBRATOR	1 4

Valhalla Scientific Inc

PARTS LIST

REF. DES.	V.S. P/N	DESCRIPTION	MFG.	MFG. P/N
J 1, 2	5-10001	BINDING POST RED	83330	1517-RED
J 3, 4	5-10003	BINDING POST BLK	83330	1517-BLK
Q 1, 2, 3, 4	3-10016	TRANSISTOR FET	Siliconix	VN66AK
Q 5, 6, 21, 22	3-10014	TRANSISTOR DARLINGTON	27014	2N5305
Q 7-19	3-10015	TRANSISTOR NPN	04713	MJE3439
Q 20	3-10017	TRANSISTOR POWER	DELCO	DTS-801
Q 23	3-10010	TRANSISTOR PNP	04713	2N4402
K 1, 2	5-03035	RELAY COIL	GORDOS	C12
4 ea	5-03036	RELAY REED	GORDOS	MR138
R 1, 3, 5, 7, 9, 13, 52, 58, 123, 124, 125	1-01081	RES FXD 100K 1/4W 5%	81349	RC07GF104J
R 2, 4, 6, 8, 10, 12, 38, 57, 136, 137, 138, 139	1-01041	RES FXD 1K 1/4W 5%	81349	RC07GF102J
R 14	1-01014	RES FXD 39Ω 1/4W 5%	81349	RC07GF390J
R 15	1-30011	RES FXD 1K 10W	91637	RS-10-1K
R 16, 19, 21		FACTORY SELECT		
R 41	1-50013	RES VAR 1K	80294	3255W-1K
R 18	1-50024	RES VAR 100K	80294	3255W-100K
R 20	1-10111	RES FXD 1.24M 1%	81349	RN60C1244F
R 22	1-01100	RES FXD 1M 1/4W 5%	81349	RC07GF105J
R 23	1-50033	RES VAR 50Ω	80294	3255W-50Ω
R 24, 30	1-20065	RES FXD 49.75K .01%	Ultronix	1-20065
R 26	1-50028	RES VAR 50K	80294	3255W-50K
R 27	1-01089	RES FXD 300K 1/4W 5%	81349	RC07GF304J
R 28	1-01007	RES FXD 10Ω 1/4W 5%	81349	RC07GF100J
R 29, 122	1-10145	RES FXD 2K 1/4W 5%	81349	RC07GF202J
R 31	1-01088	RES FXD 270K 1/4W 5%	81349	RC07GF274J
R 32, 44, 47, 48, 50, 66	1-01053	RES FXD 4.7K 1/4W 5%	81349	RC07GF472J
R 33, 34, 35, 36	1-01087	RES FXD 240K 1/4W 5%	81349	RC07GF244J
R 37	1-01083	RES FXD 150K 1/4W 5%	81349	RC07GF154J
R 39	1-20066	RES FXD 200K .01%	Ultronix	1-20066
R 40A, 40B	1-20067	RES FXD 899.75KΩ.01%	Ultronix	1-20067
R 42, 62, 70	1-01063	RES FXD 15K 1/4W 5%	81349	RC07GF153J
R 43, 59, 60, 63, 64, 65, 140, 141, 146	1-01061	RES FXD 10K 1/4W 5%	81349	RC07GF103J
R 45	1-20068	RES FXD 19.995K .01%	Ultronix	1-20068
R 46	1-50018	RES VAR 10Ω	80294	3255W-10Ω
R 49	1-01047	RES FXD 2.4K 1/4W 5%	81349	RC07GF242J
R 51	1-01119	RES FXD 10M 1/4W 5%	81349	RC07GF106J
R 53, 54, 55, 56	1-01031	RES FXD 390Ω 1/4W 5%	81349	RC07GF391J
R 61	1-01021	RES FXD 100Ω 1/4W 5%	81349	RC07GF101J
R 67, 68, 71	1-01043	RES FXD 1.5K 1/4W 5%	81349	RC07GF152J

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PARTS LIST

REF. DES.	V.S. P/N	DESCRIPTION	MFG.	MFG. P/N
R 69	1-01049	RES FXD 3K 1/4W 5%	81349	RC07GF302J
R 72-121, 126	1-01033	RES FXD 470Ω 1/4W 5%	81349	RC07GF471J
R 127	1-01026	RES FXD 220Ω 1/4W 5%	81349	RC07GF221J
R 17	1-20016	RES FXD 1K .05%	00002	J110-1K
R 128-131, 142-145	1-01085	RES FXD 200K 1/4W 5%	81349	RC07GF204J
R 132	1-30012	RES FXD 500K 1W	81349	RN75D5003F
R 133, 134	1-01108	RES FXD 3M 1/4W 5%	81349	RC07GF305J
R 147	1-30013	RES FXD 100Ω 1/2W	81349	RC20GF101J
R 25, 135	1-20035	RES FXD 5K .01%	00002	J110-5K
S 10	5-03030	PUSH BUTTON SWITCH	71590	F20-EE-FA200-ZF
S 1-6	5-03033	BCD ROTARY SWITCH	71590	PA0160-0346
S 7	5-03031	2 POLE 3 POSITION ROTARY	71590	SA-203-3F-000
S 8, 9	5-03032	PUSHBUTTON SWITCH	ALCO	TPF11CG-PC (0)
S 11	5-03034	115/230 SLIDESWITCH	82389	47227LFR
T 1	4-20025	HIGH VOLTAGE TRANSFORMER	53504	2701-102
T 2	4-20026	POWER TRANSFORMER	53504	2701-103
Y 1	5-02000	1MHz CRYSTAL		HC6-1MHz
1 ea	4-10220	CHASSIS	53504	2701-204A
2 ea	4-10170	BEZEL	53504	2701-200A
2 ea	4-10171	RACK BRACKET	53504	2701-201
1 ea	4-10186	FRONT PANEL	53504	2701-202B
2 ea	4-10187	P.C. SUPPORT & HEAT-SINK	53504	2701-203
2 ea	4-10180	TOP & BOTTOM COVERS	53504	2053-205
1 ea	4-30052	P.C. BOARD DISPLAY	53504	2701-700B
1 ea	4-30053	P.C. BOARD MAIN	53504	2701-701B
1 ea	5-10166	LINE FILTER	CDE	APF600CEE
1 ea	5-10067	POWER CORD	70903	17250
10 ea	5-10156	TINNERMAN NUTS		C8094-632-24
7 ea	5-10165	KNOBS	ROGAN	GR112D/2 SETSCREWS
1 ea	5-10095	STANDOFF	SMITH	8242
1 ea	5-10173	STANDOFF	SMITH	8349
1 ea	5-10018	FUSE HOLDER		42004A
12 ea		4-40 x 3/8" LG NYLON HEAD SCREWS		
20 ea		6-32 x 3/8" LG PAN HEAD SCREWS		
8 ea	5-10133	INTERCONNECT HEADER	AP	929835-04-08
2 ea	5-10167	INSULATED STANDOFF	USCEO	1450B7-11
4 ea		6-32 x 1/2 LG NYLON SCREW		
7 ea	5-10008	16 PIN SOCKET		CS2016B
1 ea	5-10058	HEAT SINK	THERMOLY	6004B-2
12 ea		6-32 x 3/8" FLAT HEAD PHIL BLACK OXIDE SCREW		

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PARTS LIST

REF. DES.	V.S. P/N	DESCRIPTION	MFG.	MFG. P/N
12 ea		TRANSISTOR INSULATORS		
1 ea		HEATSINK INSULATOR		
2 ea		4-40 x 1/2" LG PAN HEAD SCREW		
4 ea	5-10174	PEM CHASSIS FASTENERS PEM		5-632-2
1 ea		18" x 3/16" HEATSHRINK TUBING		

MODEL:	TITLE:	SHT	OF
2701	DC VOLTAGE CALIBRATOR	4	4

FEDERAL SUPPLY CODE
for
MANUFACTURERS CATALOGING HANDBOOK H4-1

00001	Monsanto, Electronic Special Products, Cupertino, Calif.
00656	Aerovox Corporation, New Bedford, Mass
00853	Sangamo Electric Company, Pickens, S.C.
01121	Allen-Bradley Company, Milwaukee, Wisc.
01255	Litton Industries, Inc., Beverly Hills, Calif.
01281	T R W Semiconductors, Inc., Lawndale, Calif.
01295	Texas Instruments, Inc., Dallas, Texas
02335	Fairchild Controls Corp., Hicksville, LI, N.Y.
02660	Amphenol Corporation, Broadview, N.Y.
03507	General Electric Company, Syracuse, N.Y.
04713	Motorola Semiconductor Prod., Inc., Phoenix, Ariz.
04963	3-M, St. Paul, Minn.
05276	Pomona Electronics Co., Inc., Pomona, Calif.
05397	Kemet, Union Carbide Corp., Cleveland, Ohio
05820	Wakefield Engineering, Inc., Wakefield, Mass.
07088	Kelvin Electric Company, Van Nuys, Calif.
07256	Silicon Transistor Corp., Garden City, N.Y.
07263	Fairchild Camera and Instr. Corp., Mt. View, Calif.
07716	I R C, Incorporated, Burlington, Iowa
07910	Continental Devices, Hawthorne, Calif.
08065	Accurate Rubber and Plastics Co., San Diego, Calif.
09026	Babcock Electronics Corp., Costa Mesa, Calif.
12405	Hysol Corporation, El Monte, Calif.
12406	Elpac, Incorporated, Fullerton, Calif.
12697	Clarostat Mfg. Co., Incorporated, Dover, N.H.
13454	Texas Crystals, River Grove, Ill.
14655	Cornell-Dubilier Elect. Corp., Newark, N.J.
14752	Electro Cube, Incorporated, San Gabriel, Calif.
16758	Delco Radio Div., General Motors, Kokomo, Ind.
17838	Mektron, California General, Inc., Chula Vista, Calif.
18324	Signetics, Sunnyvale, Calif.
18722	R C A, Mountaintop, Pa.
21604	Buckeye Stamping Company, Columbus, Ohio
25684	Victoreen Instrument Co., Inc., Oak Lawn, Ill.
27014	National Semi-Conductor Corp., Santa Clara, Calif.
27556	IMB Electronic Products, Santa Fe Springs, Calif.
28480	Hewlett-Packard Co., Palo Alto, Calif.
30983	Electra/Midland, San Diego, Calif.
44655	Ohmite Manufacturing Company, Skokie, Ill.
71279	Cambridge Thermionic Corp., Cambridge, Mass.
71400	Bussmann Mfg. Div., McGraw-Edison Co., St. Louis, Mo.
71450	CTS Corporation, Elkhart, Ind.
71468	ITT Cannon Electric, Inc., Los Angeles, Calif.
71590	Centralab Div., Globe-Union, Inc., Milwaukee, Wisc.
71785	Cinch Manufacturing Company, Chicago, Ill.
73899	J F D Electronics Company, Brooklyn, N.Y.
75915	Littlefuse, Incorporated, Des Plaines, Ill.
76055	Mallory Controls, Frankfort, Ind.
76493	J. W. Miller Company, Los Angeles, Calif.
78488	Stackpole Carbon Company, St. Marys, Pa.
80294	Bourns, Incorporated, Riverside, Calif.
81095	Triad Transformer Corp., Venice, Calif.
81312	Winchester Electronics, Oakville, Ct.
81349	Military Spec., Standardization Division, Chicago, Ill.
82389	Switchcraft, Incorporated, Chicago, Ill.
83330	Herman H. Smith, Inc., Brooklyn, N.Y.
84171	Arco Electronics, Inc., Great Neck, N.Y.
86684	R C A, Harrison, N.J.
88245	Useco Div., Litton Industries, Van Nuys, Calif.
90201	Mallory Capacitor Company, Indianapolis, Ind.
91637	Dale Electronics, Inc., Columbus, Neb.
91929	Micro Switch Div., Honeywell, Inc., Freeport, Ill.
92194	Alpha Wire Corporation, Elizabeth, N.J.
93332	Sylvania Electric Products, Inc., Woburn, Mass
98978	IERC, Burbank, Calif.
00002	Jordan Electronics, Van Nuys, Calif.
53504	Valhalla Scientific, Inc., San Diego, Calif.

MODEL 2701
PROGRAMMABLE PRECISION DC VOLTAGE CALIBRATOR

ORDERING INFORMATION

MODEL 2701	PROGRAMMABLE PRECISION DC VOLTAGE CALIBRATOR
OPTION IEEE-488	IEEE-488 INTERFACE MODULE
OPTION C	48-INCH SHIELDED CABLE SET (Combination Alligator Clips and Banana Plugs
OPTION BBC	48-INCH SHIELDED CABLE SET (Dual Banana Plugs)

FOB: San Diego, California

Terms:Net 30 Days

DELIVERY
Stock to 30 days

Valhalla Scientific Inc.

7707 Convoy Ct., San Diego, California 92111